DEC STD 067-1 Electrostatic Discharge-Sensitive Devices: In Engineering Facilities

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ABSTRACT: This section of DEC STD 067 provides detailed requirements and guidelines for ESD prevention and protection in engineering facilities.

APPLICABILITY: This section is mandatory for all Digital facilities and personnel involved in engineering a new or existing product. It applies to all work areas not involved in manufacturing or field operations disciplines; these disciplines are covered in other sections of DEC STD 067.

STATUS: APPROVED 27-Dec-1989; use VTX SMC for current status.

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1 INTRODUCTION

While many devices are sensitive to electrostatic discharge (ESD) potentials of 200 volts, it is quite common for a person to be charged to 3500 volts. Devices are being damaged. Digital uses state of the art technologies in the development of products; to adequately protect these products from ESD damage, state of the art ESD-protection procedures must be employed. It is in Digital's interest to produce products that survive in electrostatically hostile areas. Return on investment dollars have been documented in Digital in ratios of $1:$10 to $1:$1000. By instituting simple protection practices of designed-in protection and eliminating materials that generate a charge, this cost can be significantly reduced.

Implementing ESD controls will increase long term product reliability by minimizing the occurrence of latent failures, reducing cost in terms of warranty service requests, and increasing customer satisfaction.

1.1 PURPOSE

Handling implies all areas where there is contact with the product, and knowledge of product sensitivities is required. Handling is done from first inception of product design through prototype stages to where manufacturing picks up the product and is then done in work areas, storage, and in transporting products between areas. For this reason, this document establishes rules for all operations of ESD control in the engineering of new products.

Existing products are frequently re-engineered. The rules in this document are also to be applied to existing engineering products.

A complete ESD control program is delineated in this document. It describes protection procedures for work and storage areas. The development and protection of products is discussed. Training requirements for engineering and related disciplines are discussed, and the equipment needed for monitoring and operating an ESD-protected area is listed. A section for additional information includes controls pertaining to nontraditional engineering applications. An abbreviated glossary is also included.

1.2 SCOPE

This engineering section of DEC STD 067 applies to all areas where prototypes and new products are handled. This includes all design and support phases of product development, all laboratories including research and development, classification and qualification laboratories, product safety and agency regulatory laboratories, and general engineering and engineering support areas. The specifications of this document may be imposed by purchasing or engineering on vendors who supply Digital .

1.3 RESPONSIBILITIES

Engineering supervisors and managers have the final responsibility for engineering areas and the personnel working in these areas. These personnel shall ensure that the grounding configurations of the work area complies with this document (heading 4). They shall ensure that the personnel involved in engineering practices are adequately trained and certified to work with devices that are sensitive to ESD (heading 6). Also, they are responsible to see that engineering personnel have the proper equipment to adequately protect a product from ESD damage (heading 7).

Engineers and engineering technicians have the responsibility to properly use the ESD-protective material supplied to their areas. They are to be aware of the susceptibility levels of new technologies used in development, as the ESD sensitivity may prevent the successful introduction of the product. They are responsible for maintaining their ESD certification or training requirements as available.

EOS/ESD (Electrical Overstress/Electrostatic Discharge) Control Engineering shall maintain this document and aid in the implementation of its procedures.

2 DEFINITION OF STATIC ELECTRICITY PHENOMENA

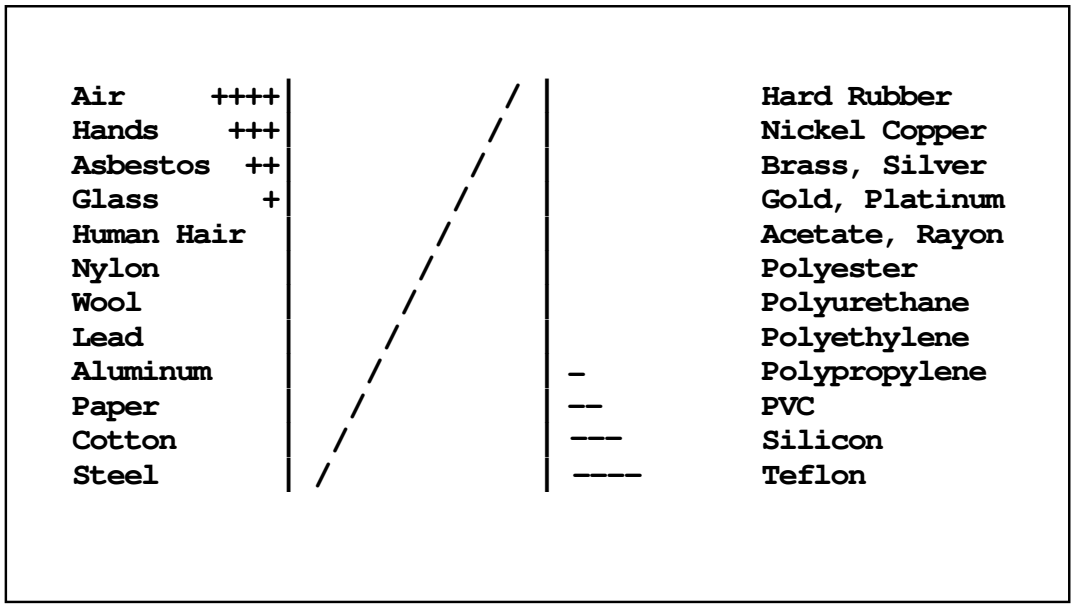
Static electricity is an electric charge that builds up on a material. An electrostatic discharge (ESD) occurs when that charge is removed to a material of a different electrostatic potential. Energy levels are governed by the relationship shown below by Equation 1.

$$W = (1/2)CV^2 \qquad 1$$

A person typically has a capacitance in the range of 100 to 400 picofarads (pF), and static voltages on a person can range up to 30,000 volts (30 kV). Higher voltages are not common on people because voltages higher than 30 kV tend to bleed off by corona discharge. This causes an energy range up to 450 millijoules (mJ). Semiconductor devices are typically destroyed by 0.2 to 2.0 mJ.

Static electricity is caused by triboelectric generation, the rubbing together or separating of two materials in intimate contact. Triboelectric generation is frequently described with a triboelectric series. See Figure 1.

Figure 1: Triboelectric Series



When two materials are brought into contact, such as hands and Teflon, the material on the more positive end, hands in this case, will charge positively, and those on the opposite end of the series will charge negatively. The farther away from each other on the triboelectric series, the more the two materials will charge. Due to conservation of charge, the charge on the one material will always be matched with an opposite but equal charge on the other material. It is important to note that triboelectric generation is governed by a variety of factors. Under different conditions, materials may not act strictly in accordance with the triboelectric series. Therefore, the triboelectric series is to be used as an information guide, not a scientific tool.

A static charge can be developed through triboelectric generation on both conductors and insulators. Conductors will discharge through a direct discharge. Insulators must be exposed to free ions to discharge. Insulators are capable of inducing a field onto a conductor. It is for this reason that insulators in the work area are so dangerous. A styrofoam coffee cup can be charged to 20 kV and repeatedly induce a field onto a conductor, causing repeated ESD events.

Conservation of charge is an important aspect of static electricity. As an object becomes charged, the only way to remove that charge is through discharge. As an object changes its shape or position relative to ground, its capacitance changes.

$$Q = CV \quad \text{or} \quad V = Q/C \qquad (2)$$

As an illustration, if an ungrounded person has a capacitance C of 330 picofarads (pF), and is charged Q to 5 microcoulombs (uC), that person will show a voltage of V = 5e-6/330e-12, or 15,000 volts (Equation 2). If that person lifts one foot from the floor, they have effectively halved their capacitance, as shown by Equation 3, where e is the dielectric constant of the material between conductors, A the area of the capacitor plate, and D the distance between the plate and ground.

$$C = eA/D \qquad (3)$$

The foot being lifted halves the area A, which halves the capacitance. Returning to Equation 2, where Q has not changed, the voltage is now doubled. When this person discharges to a sensitive device, the current can be up to 30 amperes (A). See Equations 4 and 5.

$$i = cdv/dt \qquad (4)$$

This formula is normally solved by calculus and requires the mathematical definition of all segments of the ESD voltage waveform. An approximation of the current can be calculated with Ohm's law (Equation 5).

$$I = V/R \qquad (5)$$

The human body has a typical resistance of approximately 330 ohms. This produces a current of I = 1.5e+4/330, or 45 A. It is not dangerous to the person because of the high speed of the event.

Electrical overstress (EOS) is often tied into ESD discussions. EOS is defined as any electrical phenomena outside the normal signal qualities that may cause electrical stress to a device. EOS is caused by lightning strikes, power utility problems such as power outages, utility or equipment switching, and more. ESD is a subset of EOS.

2.1 CHARACTERISTICS OF ESD

There are five separate components of an ESD event.

1. A corona radiation
2. An electric field associated with the corona
3. A changing electric field
4. A changing magnetic field associated with the discharge
5. The injected current waveform

Each ESD component can be damaging in its own way. Radiated energy induces currents onto wires. Because the ESD event is complete within 1 to 1000 nanoseconds, any wires or etch-runs in the microinch range can act as an antenna, picking up potentially damaging signals. The electric and magnetic fields likewise can induce currents and voltages onto a board or device. The injected current waveform is typically very fast, with a rise time on the order of 1 to 10 nanoseconds, and a fall time to 50 % of peak current in 5 to 200 nanoseconds. The faster the rise time, the more damaging the waveform. The lower static voltages (below 7 kV) typically have a faster rise time due to switching characteristics and various ESD simulator configurations. For this reason, lower ESD voltages can be more damaging than the higher voltages.

2.2 DEVICE SENSITIVITY

Characteristics of devices that cause sensitivity to static electricity are varied. Increased device density causes a lower threshold of energy damage. Faster signal frequencies are approaching the same speeds as the average ESD waveform, making the transient look like a signal. Low-power devices are also more sensitive to ESD. Sensitivity levels for common parts are listed in Table 1.

Table 1: Device ESD Sensitivity

Device Type	Range of ESD Sensitivity (Volts)
VMOS	30 - 1800
CMOS	30 - 4000
MOSFET	50 - 200
GaAsFET	100 - 300
EPROM	100 - 500
ECL	100 - 1500
JFET	140 - 7000
Op-Amp	190 - 2500
Film Resistors	250 - 3000
SCHOTTKY Diodes	300 - 2500
BJT	380 - 7000
SCR	600 - 1000

Sensitivity to ESD is not only a device issue. Sensitivity can be increased or decreased when the device is a part of a board or system. It is dependent on many factors, including lead or etch run-length, board capacitance or inductance, proximity to external points and sources

of ESD, the operational state of the device, environment (humidity and temperature), and more.

2.3 STATIC ELECTRICITY PROTECTION

Protection against static electricity involves protection of both the work area and the device being handled to prevent ESD damage. Protection of the work area must include all aspects of grounding personnel, work benches, and equipment, as discussed under heading 4. Device protection must include full static-electricity sensitivity testing, control of the product in terms of proper qualification, classification and incoming inspection practices, and final system testing (heading 5).

Material control and protective packaging are required for all storage and transportation of materials in and around areas sensitive to ESD. Packaging typically falls into various categories: conductive, static dissipative, and antistatic. Conductive or metalized layered materials provide the most protection from static electricity by preventing the development of a charge on the device. A metalized layered material is a combination of a conductive layer sandwiched between antistatic layers. Static-dissipative materials have a resistance between insulative and conductive materials and allow a slow bleed-off of charge. Antistatic materials do not have an associated range of resistance and are not engineered to protect the product as much as to provide a safe method of packaging less- and non-sensitive devices in a protected area. Therefore, antistatic materials can be used to package nuts and bolts, or as garbage bags. Antistatic materials should replace any miscellaneous items commonly made of insulators that are required in ESD-protected areas. See the Glossary, heading 9 or DEC STD 067-0 for full definitions of these terms. For a full description of packaging, see *DEC STD 067-2 Electrostatic Discharge-Sensitive Devices: Procedures and Protective Packaging Materials*.

3 ESD CONTROL PROGRAMS

ESD control programs consist of two major elements.

The first and most important part of an ESD control program is the proper training and certification of personnel. Training gives people a reason to protect Digital products from ESD damage. The ESD training program and requirements are listed under heading 6. Training is available internally either through EOS/ESD Control Engineering (NRO) or Customer Service Logistics Training Center (DAS).

The second part of the ESD control program is the area set up. The procedures and equipment required in an ESD-controlled area are outlined under heading 4.

One person shall be responsible for the control of static electricity at each area that is sensitive to ESD. This person is referred to here as an ESD Control Program Leader. To be effective, this position requires full management support .

3.1 TYPICAL JOB DESCRIPTION: ESD CONTROL PROGRAM LEADER

The primary responsibilities of an ESD Control Program Leader are as follows.

- Provide a contact point for collecting and distributing information on ESD.
- Deal with area personnel from technical to managerial staff, and implement the training required for full ESD control.

- Provide a single information exchange to both Digital and non-Digital groups.

This person is not required to know everything about ESD, but is required to set up a network to find the required control information for ESD.

Specific responsibilities:

- Use this standard to delineate the work area (or site) specific ESD protection program.
- Coordinate or perform audit services, and implement the recommendations of the audit report.
- Contribute to sections on ESD in engineering specifications or documentation for new and existing products or processes.
- Maintain contact with corporate and industry groups active in ESD work, stay abreast of technology advances, and implement these advances in the area as applicable.

Other responsibilities may include:

- Interface with inside and outside vendors to explain the requirements for control of ESD as they apply to operational needs.
- Aid in evaluating vendor conformance to ESD specifications.

Education should be a Bachelor of Science degree in Electrical Engineering or equivalent experience.

Job performance would be helped by experience in engineering, manufacturing, or quality control environments, along with some training in ESD phenomena.

Job complexity: Provides solutions to a wide range of ESD control problems using adaptability and imagination to provide the best solutions. The job requires good networking capabilities to locate available answers.

Impact of position: Immediately improved productivity and reliability. General improvement in meeting schedule constraints. This impacts Digital through the decrease of product and service costs, and an increase in customer satisfaction.

4 GENERAL PROTECTION PROCEDURES

4.1 WORK AREAS

Work areas are those areas where a person will come into direct contact with devices. The goal of an ESD-protected work area is to have all items at the same electrostatic potential. Triboelectric-generating materials such as notebooks, telephones, terminal cases, and paper must be controlled by chemical treatment or encasement in static dissipative plastic so as not to form a threat to devices sensitive to ESD. All nonessential materials that generate static electricity, such as untreated plastics and styrofoams, tape, rubber pads and bands, plastic tote bags, flower pots, radios, extra clothing, ash trays and smoking materials shall be prohibited from the ESD-protected work area.

4.1.1 Work Area Requirements

The work surface shall be made of or covered with a static-dissipative material attached to ground through a one megohm ±10% resistor and shall include, for each person, an attached grounding wrist strap with an integral one megohm ±10% resistor.

NOTE

No static electricity generating materials or activities shall be allowed in ESD-protected areas.

If ESD-protective flooring is employed, the flooring shall be static-dissipative floor tiles, mat, or carpeting. ESD-protective footwear shall be used. Furniture, such as chairs, shall have static-dissipative castors to ensure their connection to ground. See Figure 2 for an illustration of an ESD-protected workstation. If ESD flooring is not employed, all products must be protectively wrapped from ESD when not at a grounded workstation. Wrist straps are to be attached to ground through a one megohm ±10% resistor. See Figure 2. Table tops should be either attached to ground directly or through a one megohm ±10% resistor.

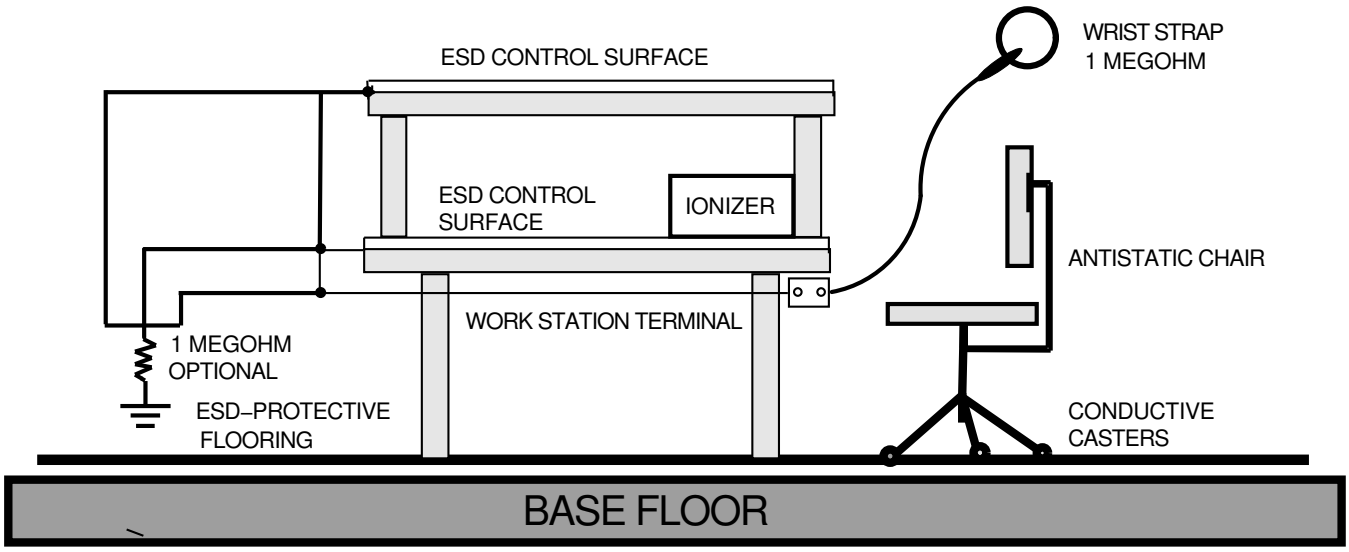
NOTE

Ground is defined as the standard building earth ground. Prior to an ESD-protective workstation's use by personnel, the ESD Control Program Leader shall review and approve all electrical connections as defined by NFPA 70, NEC Article 250 in the U.S., and/or the equivalent electrical safety grounding standard on regulation outside the U.S.

CAUTION

Parallel resistances may occur in many common but incorrect configurations of grounding a work area.

Figure 2: ESD-Protected Workstation



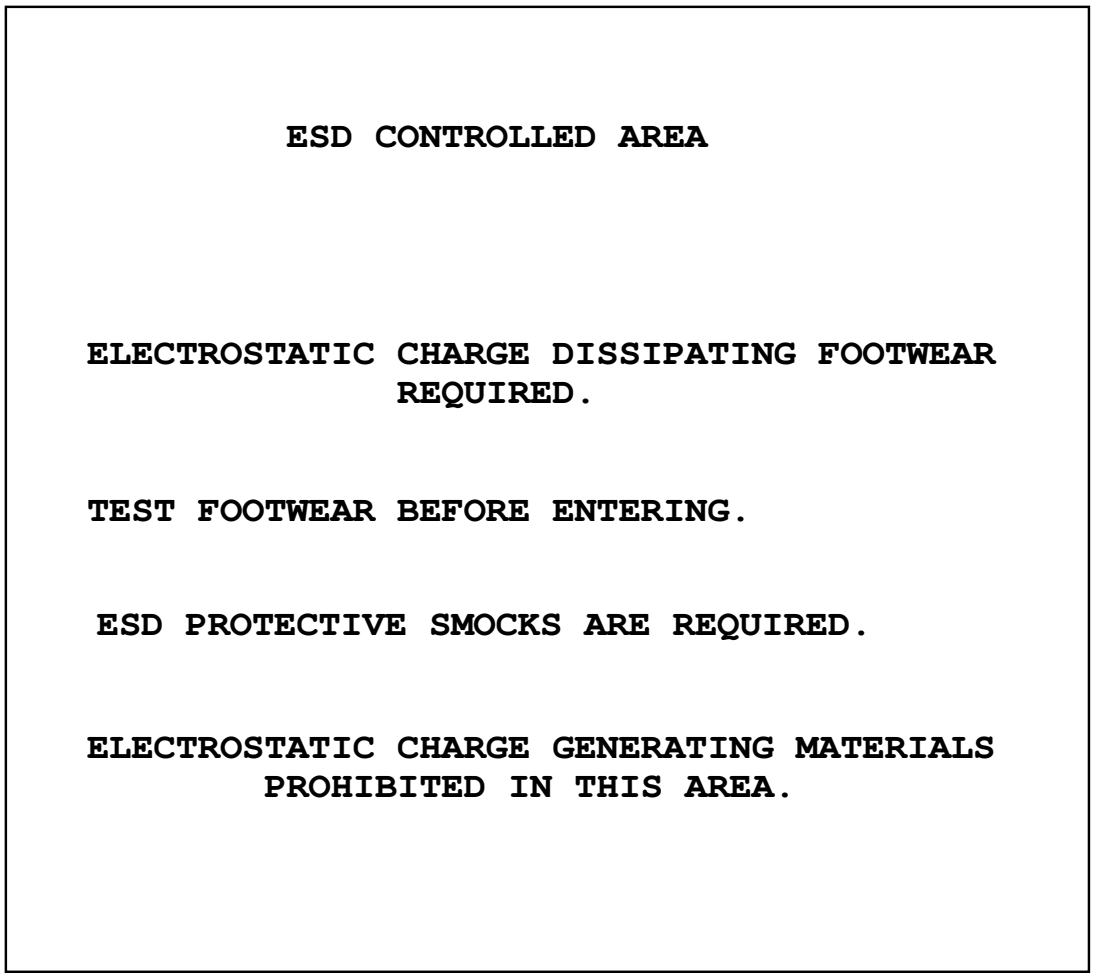
Rules:

1. ESD–Protective footwear is required.
2. Wrist strap must be worn when seated.
3. Remove all nonessential material.
4. Run ionizer during all operations.
5. Keep all modules ESD–Protection when not being worked on.
6. Treat plastic surfaces to prevent charge generation and monitor periodically.
7. Ground all containers while transferring ESD–Sensitive contents.
8. ESD smocks are required in all areas where ESD–Sensitive material is handled.

The perimeter of the ESD-protected area shall be marked with signs and floor markings as applicable.

A cautionary sign must be posted at each entrance to the ESD-controlled area. See Figure 3.

Figure 3: Typical Entrance Sign


ESD CONTROLLED AREA
ELECTROSTATIC CHARGE DISSIPATING FOOTWEAR REQUIRED.
TEST FOOTWEAR BEFORE ENTERING.
ESD PROTECTIVE SMOCKS ARE REQUIRED.
ELECTROSTATIC CHARGE GENERATING MATERIALS PROHIBITED IN THIS AREA.

Footwear testers shall be available at each entrance. Footwear testers shall indicate with a caution light if resistance is less than one megohm. The tester also shall indicate resistance over one gigaohm with a warning light and shall indicate any resistance between these extremes with a safe light indicating that the footwear is ESD protective.* Measurement tolerance is ±10%.

* Footwear of less than one megohm is unsafe in the presence of hazardous voltages.

Any paper, including that used in process documentation, can become highly charged. This depends on the fiber content, surface treatment, and relative humidity. The preferred method of control is to place the sheets in static-dissipative page protectors. An alternative is to ensure that the paper is always maintained at a distance of 12 inches from ESD-sensitive components. This method is not as reliable as page protectors.

Test equipment used at the workstation shall be grounded. Tools that are not plugged in shall be ESD controlled as appropriate, by being made of static-dissipative or antistatic materials, or by being chemically treated to not tribogenerate static electricity. If conductive tools are used, they should be checked by safety personnel to ensure that no risk to the operator exists. Soldering and desoldering tools are to conform with the requirements of *DOD STD 2000-1B Military Standard Soldering Technology*. Cleaning brushes shall have wood handles and natural bristles.

Air ionizers shall be used at workstations that require the use of insulators as an integral part of the engineering process. Tribogenerative processes, such as freeze mist and hot air guns, require ionization. If ionization is used, ionizers must be cleaned and calibrated at least quarterly or more often as required by the manufacturer.

NOTE

Air ionizers shall not be used as an alternative to proper grounding of work surfaces and personnel.

Devices brought in and removed from an ESD-protective workstation shall be packaged per *DEC STD 067-2 Electrostatic Discharge-Sensitive Devices: Procedures and Protective Packaging Materials*.

CAUTION

The use of conductive or static-dissipative work surfaces are prohibited in work environments where exposed voltages exist in excess of 250 Vdc or rms. See Heading 4 of *DEC STD 067-3 Electrostatic Discharge-Sensitive Devices: In Manufacturing Facilities* for a full description of high potential workstations.

All devices that are sensitive to ESD are to be protectively packaged at the completion of the work shift to prevent damage by maintenance or other facility crews.

Footwear and wrist strap testers shall be at each entrance to a work area protected against ESD.

The minimum requirements for product protection are determined through classification by ESD sensitivity levels. Unclassified products must be protected to the lowest ESD sensitivity level. Classification levels and the testing methods to determine these classification levels are described in *DEC STD 067-0 Electrostatic Discharge-Sensitive Devices*.

4.2 PERSONNEL

All personnel working with or coming in contact with electronic devices in engineering areas, whether they are managers, engineers, technicians or other personnel, shall comply with the following requirements.

A wrist strap with an integral one megohm +/- 10% resistor shall be worn by personnel using the work area at all times.

If static-dissipative flooring is used, personnel within the work area shall wear appropriate static-dissipative footwear (shoes, heel or toe straps).

Personnel shall wear ESD-protective smocks or lab coats when working in or passing through an ESD-protected work area.

ESD-protective smocks or lab coats shall be equipped with elastic wrists to ensure physical contact with the person.

Where personnel are required to move within the work area, static-dissipative footwear and properly grounded flooring materials are an accepted alternative to wrist straps.

4.3 STORAGE AREAS

Containers of items sensitive to ESD are not to be accepted into stock unless identified as containing ESD-sensitive items.

Items may be removed from the protective container only by a properly grounded operator at a protected workstation as described under subheads 4.1 and 4.2.

Because of the close proximity of devices sensitive to ESD, all packaging shall be protective against ESD. All packaging materials that generate static electricity shall be discarded outside of the storage area.

All subdivided lots must be carefully repackaged in protective containers prior to removal from the static-free workstation, and they must be labeled to indicate the packages contain items that are sensitive to ESD.

Storage areas must be kept neat, clean, and free of materials that generate static electricity, such as personal items, uncontrolled plastics such as notebook covers and trash can liners, and unnecessary paper.

It is the responsibility of the stockroom supervisor to ensure that all personnel using the stockroom (including temporary employees brought in for physical inventory) are familiar with the handling procedures defined in DEC STD 067.

4.4 GENERAL PROTECTION PROCEDURE

A copy of this standard should be made available to all personnel. A copy of the general protection procedure as listed here shall be posted in the work area.

1. All electronic components and assemblies are to be treated as if they are sensitive to ESD as required by device classification.
2. All materials that are sensitive to ESD shall be stored and transported inside protective bags or containers.
3. Materials sensitive to ESD may be transferred into or out of the ESD-protective container only at an ESD-controlled workstation and only while the container is grounded.
4. All personnel must be properly grounded while handling unprotected materials that are sensitive to ESD.
5. All personnel working in ESD-controlled areas shall be trained and certified in ESD control procedures. Noncertified personnel may work in the area only under the direct supervision of certified personnel.

6. ESD protective garments such as smocks, lab coats, and clean-room suits must be worn closed by personnel entering ESD-controlled areas.
7. Footwear that dissipates electrostatic charges must be worn on both feet by personnel entering ESD-controlled areas.
8. All footwear (shoes, heel grounders, and toe grounders) must be tested before entering an ESD-controlled area. Resistance from hand to floor must not exceed one gigaohm.
9. Wrist-strap grounds must be worn by all personnel who are seated while working with components that are sensitive to ESD.
10. Wrist straps must be tested daily (minimum). Resistance through the cord, wrist band, and wrist must be at least one megohm ± 10, but must not exceed 10 megohms.
11. All tools, including soldering and desoldering instruments, shall measure no more than 0.2 volts on their tips.
12. Grounding at workstations where electric shock is a hazard shall be designed on an individual basis. Stations must be certified by the responsible safety, electrical, and ESD engineers prior to initial operation.
13. Grounding of test equipment and tools must be through the safety ground-connection of the power outlet, not through the workstation's ESD ground (which is not designed to carry high current).
14. Work surfaces of less than 1e+6 ohms/sq are not to be used in ESD protective work areas.
15. Materials that generate a charge and are not required for workstation operation are not allowed in ESD-protected areas. Required materials that generate a triboelectric charge must be controlled by surface treatment and/or ionization.
16. Books, notebooks, and process documentation shall not be capable of triboelectric generation or shall be kept at least 12 inches from components sensitive to ESD.
17. Drawings, process sheets, and other shop-floor documents must express ESD control precautions and procedures as applicable to the process described.
18. Where necessary, ionizers shall be placed at the workstation so that the airstream washes the area prone to triboelectric charging, and shall be inspected, cleaned, and balanced at least quarterly or more frequently, as experience dictates or as the manufacturer requires.

4.5 TRANSPORTATION

All items sensitive to ESD must be received in an ESD-protective container that is protective to the ESD-sensitivity classification level. Packaging issues are addressed in DEC STD 067-2.

Items that are sensitive to ESD are to remain in their protective packaging except when being worked on in the protected work area.

4.6 SAFETY

Safety is extremely important to establish ESD-controlled areas. The variable used to determine the criteria for shock intensity is current.

ESD protective work benches must be grounded to eliminate the risk of electric shock. A soft ground may be incorporated with the appropriate resistance (1.0 megohm ±10%; because the work bench surface must have a resistance greater than one megohm/sq, the resistor is not necessary. The material resistance is sufficient to limit current.

CAUTION

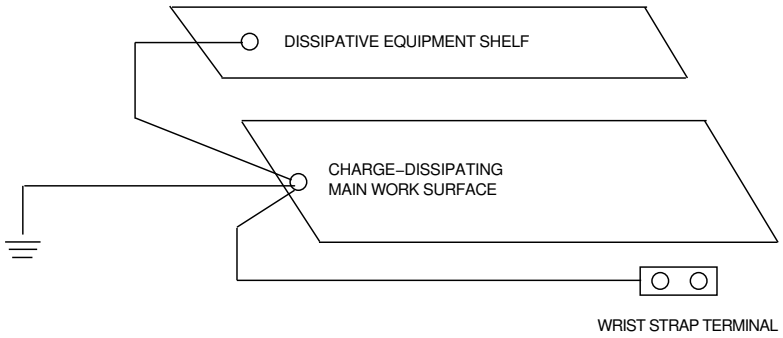
The required one megohm resistor is valid only for workstations with less than 260 Vdc or RMS available to the operator. In setting up stations with more than 260 Vdc, refer to the high voltage workstation description in DEC STD 067-3.

Static-dissipative bench tops must have a surface resistance of 1e+6 to 1e+10 and be properly grounded according to the manufacturer's instructions.

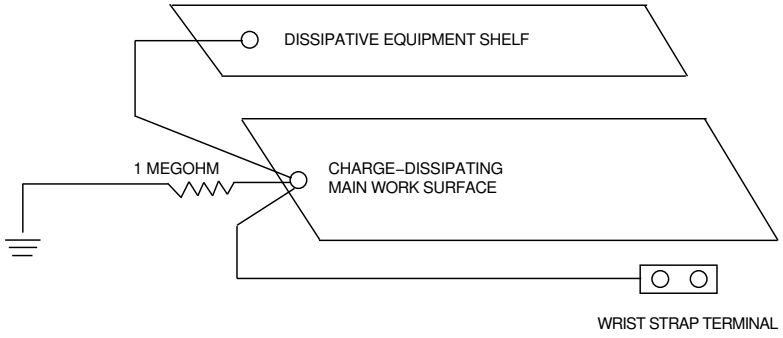
To promote safety, observe the following precautions.

1. Use current limiting resistors of sufficient size to be mechanically durable. A half watt resistor is sufficient.
2. Ground cable connections must be continuous and permanent.
3. Resistances to ground must be high enough to limit leakage current to personnel to 0.5 mA maximum, based on the highest voltage source accessible by grounded personnel. Such voltage sources include power sources and test equipment.
4. The ground cable and connection material must be of sufficient mechanical strength to prevent unintentional disconnection from ground. Ring lug or threaded fastener connections are recommended over snaps and banana jacks.
5. The grounding points for workbench tops, floor mats, ground straps, and other ESD-protected area grounds used to discharge static electricity must be connected to a hard ground (approved by an electrical inspector). Connection may be made through a 1.0 megohm ±10% resistor (see Figure 1).
6. Connect the wrist strap to earth through the bench top ground point. Do not connect workbenches and mats in series (see Figure 4).
7. Wrist, ankle, and leg ground-straps shall have a minimum resistance of 1.0 megohm ±10% to protect the person from electrical shock hazards.
8. For flooring or mats laid over insulating floors, connect flooring or mats to ground through current-limiting resistances (1.0 megohm ±10%) every 6 to 10 feet. After installation, a resistance check from each tie point to ground shall be performed to ensure that unsafe parallel paths to ground have not been created. The measured resistance shall be 1.0 megohm ±10%. For mats laid over concrete or conductive flooring, wiring will not be necessary. The finished floor shall be tested according to NFPA 99.

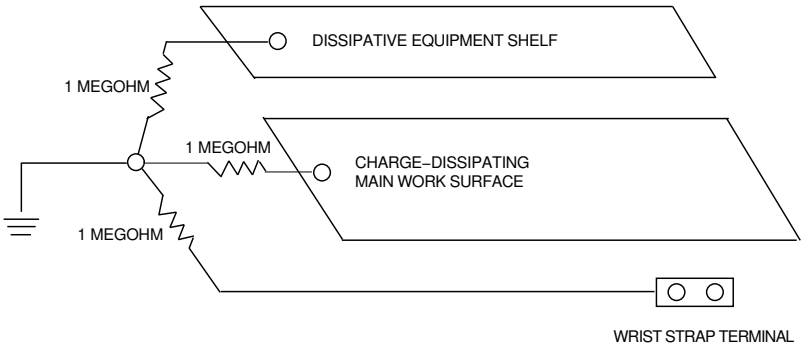
Figure 4: Line Drawing of Grounding Circuit



PREFERRED METHOD



ACCEPTABLE METHOD



ACCEPTABLE METHOD

5 PRODUCT TESTING

Products needing protection from ESD commonly fall into three groups: semiconductor technologies (including discrete semiconductors), film components and integrated circuits, and modules and system level products. Other products, such as materials for packaging, work areas, or cabinets are dealt with in DEC STD 067-2 and DEC STD 067-5. This section discusses the testing of these three areas, by describing test methodologies, standardized test methods, and ESD waveform models available to help develop testing procedures. Information is included on how to use this in the development of qualification parameters, characterization procedures, and product specifications.

5.1 ESD SENSITIVITY TEST METHODOLOGY

Test procedures shall be developed with consideration for static electricity control.

Test procedures written to test a product for sensitivity to static electricity shall keep all of the following conditions in check as they can affect test results.

- Ambient humidity
- Ambient temperature
- Product cleanliness
- Amount of human use and handling in normal operation
- Location of use
- Transportation issues (to point of use, and so forth)
- Life cycle
- Expectancies
- Field service requirements
- Operator requirements (if any)

ESD testing is commonly done with ESD waveform simulators. There are many styles of waveform simulators available, including gun shaped, hand held, or vane shaped, to simulate the actual ESD event (such as a human, a charged device, or a furniture discharge). Each simulator may have a variety of discharge networks and discharge tips that comply with industry standards or tested descriptions of actual ESD waveforms. The most common discharge tips are the ball discharge tip (commonly used for air and fixed-gap discharge, and human body model (HBM) testing), and the point discharge tip (commonly used for direct discharge and charged-device-model (CDM) testing).

The three discharge methods are current injection, fixed gap, and approach and discharge.

1. Current injection is done by resting the discharge tip on the device under test (DUT) and triggering the discharge. This option may not be available on all simulators. This waveform is repeatable and is often used for life testing or multiple surging due to the relative ease of test set up.
2. Fixed-gap testing is done by setting the discharge unit at a predetermined distance from the DUT so that a discharge at the required static voltage level will occur and trigger the discharge. This option may not be available on all simulators. The distance should be the farthest point from the DUT where a discharge will still occur at the test voltage.

This method has been found to be more repeatable than approach-and-discharge testing, but this method tends to lessen the impact of the waveform due to increased rise times.

3. Approach and discharge testing is done by charging the simulator away from the DUT and approaching it with a 'loaded gun'. This is a highly dynamic test, depending heavily on approach speed and environmental factors. Therefore, it can be the most damaging way to test. The fastest rise times in ESD simulator testing have been recorded by this method. Approach and discharge testing is the most realistic method of testing. It does not, however, lend itself to automation as easily as the other two methods of testing, nor is it a repeatable form of testing.

Evidence indicates that stress hardening may occur in step stressing and may affect the sensitivity levels of devices. It has been found in testing CMOS devices that the damage thresholds of the devices increase with step-stress testing (see Randy Hull, *Stress Hardening of Damage Thresholds Due to Cumulative ESD Pulse Testing, EOS/ESD Symposium Proceedings, 1988*). The opposite phenomena has been noted in some devices, where step stressing can lower the damage threshold. It is sufficient to say that different structures can affect the ESD sensitivity in positive or negative directions, and should be noted in designing test methods.

5.2 AVAILABLE STANDARD TESTS AND ESD WAVEFORM MODELS

Human body models (HBM) and charged device models (CDM) are commonly described as capacitance and resistance. The circuit is actually much more complex; but these values coupled with various rise and fall times are what describe the ESD waveforms. The models that are commercially available and in use in Digital are listed in Table 2. Keep in mind that many standardized and available HBM and CDM test circuits may be actuated differently by each ESD simulator manufacturer, resulting in a different waveform in the dynamic state.

Table 2: Standardized Human Body and Charged Device Models

Standard	R (Ohms)	C (pF)	Typical Use
IEC 801-2	330	150	HBM for system testing
ECMA TR-40	15	variable	Furniture CDM, system testing
MIL-STD-883 Method 3015.6	1500	100	HBM for IC testing

Field effects are a legitimate problem and are being studied. Field attenuation is tested as directed in *DEC STD 103-0 Electromagnetic Compatibility (EMC) Hardware Design Requirements* and is called for in purchase specifications for many products.

5.2.1 Internal Documents

5.2.1.1 DEC STD 052-4 Local Direct Connection (No Modem) for Serial Asynchronous Terminals and System Interfaces

This document applies to DEC423 products. It specifies pass/fail limits of no permanent damage at or before 25 kV. This standard is not required for non-DEC423 products, but is often used to develop test plans for other communication systems. The actual test is five surges of both positive and negative polarities at each level: 1 kV, 2kV, 3kV, 4kV, 5kV, 6kV,

7kV, 8kV, 9kV, 10 kV, 15 kV, 20 kV, and 25 kV. Testing is performed with a MIL-STD-883 probe (100 pF, 1500 ohms). This standard also describes electrical overstress (EOS) testing for DEC423 products. Refer to DEC STD 052-4, subhead 3.1. In addition, this standard lists methods to design-in protection from both EOS and ESD. DEC STD 052-4 specifies protection devices, provides Digital part numbers, and notes typical usage.

5.2.1.2 DEC STD 103-0 Electromagnetic Compatibility (EMC) Hardware Design Requirements

This standard deals with EMI/RFI phenomena on a system level, but it includes one section on electrostatic testing. This standard requires that all Digital products be submitted for testing when completed and configured for functionality. The testing calls for surging the system at operator accessible points. Each of these points is surged 20 times at each test level: 2 kV, 3 kV, 4 kV, 5 kV, 6 kV, 8 kV, 10 kV, 12 kV, and 15 kV. Test limits are summarized in Table 3.

Table 3: DEC STD 103-0 Summary of Test Requirements

Failure Type	Equipment Type	None Permitted At or Under
Hard failure (implying operator intervention required for continued functionality):		
	EDP equipment	10 kV
	Office equipment	12 kV
Hardware damage (implying actual equipment damage):		
	EDP equipment	15 kV
	Office equipment	15 kV

5.2.1.3 Digital Product Specifications

Components are specified in Digital specifications under classes 19, 20, and 21. The general specification for these classes, such as 19-00000-GS, define the required testing specifications. They also reference documents that give step-by-step instructions for test procedures.

Modules are not specified individually. It is possible to treat modules as individual components and test them with specifications adapted from component-test specifications. It is also possible to describe the sensitivity level of the module by the level of the most sensitive device on the module. This may not be accurate, because the sensitivity of the module may be increased by the antenna effects of the etch runs or decreased by capacitive effects.

Systems are developed with Digital product specifications that address ESD testing requirements. Systems that are in the process of development can be specified by referring to similar product specifications for guidance or by using this document to ensure complete testing.

5.2.2 External Documents

This document lists only a few of the available external standards about ESD testing. The standards described here are currently used to test devices and materials at Digital.

5.2.2.1 IEC 801-2 Electromagnetic Compatibility for Industrial-Process Measurement and Control Equipment, Part 2: Electrostatic Discharge Requirements, Draft 4

International Electrotechnical Commission describes ESD testing requirements, test generators, test setups, and procedures. IEC recommends using the ESD simulation HBM of 330 ohms, 150 pF for system testing.

5.2.2.2 MIL-STD-883, Method 3015.6 ESD Sensitivity Classification

This document describes, in detail, a test method for classifying ESD sensitivity levels of ICs. It recommends using the ESD simulation HBM of 1500 ohms, 100 pF for IC testing.

5.2.2.3 ECMA TR-40

European Computer Manufacturers Association describes ESD simulator parameters and testing procedures, and recommends the use of a 15 ohm, variable-capacitance tester in a vane type assembly as a furniture CDM for system testing.

5.3 DEVELOPMENT OF CHARACTERIZATION, QUALIFICATION PROCEDURES, AND PRODUCT SPECIFICATIONS

In theory, all Digital products have specifications that include references to testing procedures. This is not always the case. For new products, ESD testing requirements must be added.

ESD sensitivity is at its highest in the design phases, when electronics are exposed. Testing should be developed with ESD events in mind.

Static electricity is caused by triboelectric generation. Devices must be tested to ensure that they do not triboelectrically generate with materials or items they must come in contact with (such as packaging materials, human hands (HBMs), automated testing or insertion machines (CDMs)). Measuring triboelectric generation is frequently done with a Faraday cup, where the device under test (DUT) is agitated against another material in a specified manner (time and amount of agitation) and dropped into a Faraday cup. This is standardized in EIA 541 *Packaging Material Standard for ESD Sensitive Items*. For larger modules and systems, dropping the product into a cup may not be feasible. Therefore, a secondary method of testing for triboelectric generation involves the use of a static field meter. In this method, the DUT is rubbed with the material in a specified manner, and the electric field is measured. Variables that may be added are powered on/off states and environmental conditions. Environmental conditions should be recorded for all testing.

Devices should be tested for sensitivity to a direct ESD discharge. Testing procedures can be developed using the information on discharge methods and various standardized HBMs and CDMs. Information on this is addressed by the documents listed under subheads 5.2.2.1 to 5.2.2.3. Environmental conditions should be recorded. There are many standardized versions of the ESD sensitivity test.

Devices must also be looked at to ensure that their sensitivity to field effects will not cause latent or hard failures. DUTs should be placed in the presence of an electrostatic field by placing them near an isolated charged plane, and discharging the plane. "Near" should be defined in respect to the size of the DUT, and the charged plane should be of a size comparable to the DUT. This testing can be done in powered on and off states, and the environmental conditions during testing should be recorded.

By taking the initiative to design this sort of protection into Digital products, product reliability is greatly increased.

6 TRAINING REQUIREMENTS

Training is the key element of an ESD control program. With training, the elements of the work area setup are understood and implemented. Failure mechanisms are known and avoided by conscious decision. Certification is maintained to enhance product reliability.

Current standards recommend training of all personnel involved in handling materials sensitive to ESD. According to MIL-STD-1686A *Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment*, training is recommended for all personnel who would come into contact with ESD-sensitive devices, no matter how casual the contact. This is to include managers and site facility personnel who do not usually handle the devices, but may temporarily come into contact with them.

Training is currently available internally through EOS/ESD Control Engineering (NRO), and Field Service (DAS). Externally developed courses are also available.

6.1 DEVELOPMENT OF A TRAINING COURSE

Training shall include a basic course and whatever specific applications that are required. The course is found to be most effective when it follows the outline presented here. For employee certification, the listed points must be presented, and the student must demonstrate an understanding of the concepts.

1. What is ESD? Where does it come from?
   - Basic physics of static electricity
   - Triboelectric generation
   - ESD definitions and components
   - Speed and energy levels of common ESD waveforms
   - Applicable statistics on the cost of ESD
   - Cost awareness: time, product, and customer satisfaction losses
2. What can you do to prevent or control ESD?
   - ESD prevention practices, for facility, work area, and personnel
   - Use of wrist strap, smock, ESD protective footwear
   - Guidelines discussed in subhead 4 of this document
   - Key role of the operating personnel is stressed
   - ESD Control program cannot function without full commitment of all personnel involved
3. Where can you get help?
   - Digital standards (103-0, 052-4, and all sections of 067)
   - EOS/ESD Control Engineering (NRO)
   - External literature and suppliers of ESD control equipment

The course should be basically technical in nature, geared to the understanding level of the student. The course should be directed to the student's concern. Teaching students with examples in their area of concern facilitates understanding and compliance with this standard.

The course works best with many hands-on examples and experiments. Demonstration tools for training have been developed and are being assigned Digital part numbers. The ordering information is available from EOS/ESD Control Engineering (NRO).

6.2 ESD CONTROL CERTIFICATION

Certification shall be possible after the completion of a basic course in static electricity control, following the outline given under subhead 6.1. A test on the concepts and controls of ESD (approximately 20 questions) shall be given. Successful completion for certification is based on correctly answering at least 80% of the questions. The purpose of the test is not to trick the student, but to ensure the comprehension level of the student, and to reiterate the key points of the course.

Certification cards shall be issued to employees who have satisfied the requirements under subhead 6.1. The card shall be prominently displayed and/or presented on request. Certification cards shall include the employee's name and badge number, original certification and expiration dates, and the words *ESD Control Certified*.

Recertification shall be done yearly, with a refresher course and a brief test. Recertification shall be noted on the certification card with a dated sticker.

7 NECESSARY ESD CONTROL EQUIPMENT AND GENERAL EQUIPMENT CONCERNS

7.1 ESD CONTROL EQUIPMENT

In engineering work areas, the following ESD control equipment may be used.

- Footwear and wrist strap checker at each entrance
- Wrist straps and smocks for all personnel working in the area
- Extra wrist straps and heel/toe grounders for people visiting work areas
- Conductive flooring or floor mats connected to earth ground through a one megohm resistor
- Static-dissipative bench tops or mats connected to earth ground (may be through a one-megohm resistor)
- Simple electrostatic field meter

Consult recommended product lists or qualified product lists for purchasing information.

7.2 GENERAL EQUIPMENT CONCERNS

Engineering areas are generally full of many different types of testing and prototype equipment. To prevent ESD, it is important to check this equipment for its safety from static electricity.

Equipment should not tribogenerate. Painted and plastic surfaces should be checked with a static electricity field meter by rubbing a hand across the surface and reading the field with the meter. See the manufacturer's instructions for more information on the use of the electrostatic field meter.

Equipment that does tribogenerate should be coated with a topical antistat or be replaced. The antistat should be checked weekly until wear patterns can be established. Then the topical antistat should be reapplied at the determined periodic rate. Equipment such as plastic solder suckers that are not made of conductive or static-dissipative plastics should be replaced, since they are not easily coated. If, however, this equipment is coated, the antistat will not last long because of constant handling and excessive heats.

Equipment grounding should be checked for completeness.

8 ADDITIONAL INFORMATION - NONTRADITIONAL ENGINEERING APPLICATIONS

Engineers who do not work directly in semiconductor technologies must also be aware of ESD protection. Static electricity can damage everything from electronic controls on HVAC equipment to terminals where mail is being read. Electric and magnetic fields are everywhere, and can induce ESD events into equipment.

These engineering functions, including plant engineering, site safety, and general facility functions, must be monitored by the ESD Control Program Leader for proper levels of education and training. The ESD Control Program Leader must also be aware of all materials that enter the facility.

APPENDIX A

REFERENCED DOCUMENTS

A.1 Internal Documents

EL-Class Number	Document Title
EL-00052-04	*DEC STD 052-4 Local Direct Connection (No Modem) for Serial Asynchronous Terminals and System Interfaces.*
EL-00067-00	*DEC STD 067-0 Electrostatic Discharge-Sensitive Devices*
EL-00067-02	*DEC STD 067-2 Electrostatic Discharge-Sensitive Devices: Procedures and Protective Packaging Materials (proposed)*
EL-00067-03	*DEC STD 067-3 Electrostatic Discharge-Sensitive Devices: In Manufacturing Facilities (proposed)*
EL-00067-04	*DEC STD 067-4 Electrostatic Discharge-Sensitive Devices: In Customer Service Areas (proposed)*
EL-00067-05	*DEC STD 067-5 Electrostatic Discharge-Sensitive Devices: Related Materials and Products Section (proposed)*
EL-00103-00	*DEC STD 103-0 Electromagnetic Compatibility (EMC) Hardware Design Requirements*
EL-00119-00	*DEC STD 119-0 Digital Product Safety - Introduction and General Requirements*
EL-00178-00	*DEC STD 178-0 Digital Identification Marking Requirements - Introduction*
EL-MF277-00	*Electrical Safety Product Test Procedure*

Use VTX SMC to order copies of EL-class documents from Standards and Methods Control. Send distribution questions to JOKUR::SMC or call DTN: 234-4423.

A.2 External Documents

Number	Document Title
ANSI/NFPA 99	*Health Care Facilities, Section 3-3.6.2: Conductive Flooring, 1987.*
Electric Code 1987 Handbook, Section 12-4.1.3.8, NFPA, Fourth Edition.	*American National Standard Institute/National Fire Protection Association* *Batterymarch Park* *Quincy, MA 02269*
DOD-STD-2000-1B	*Military Standard Soldering Technology* Naval Publications and Forms Center 5801 Tabor Avenue Philadelphia, PA 19120

Number	Document Title
MIL-STD-883C	*Method 3015.6 ESD Sensitivity Classification, 12 February 1988. (HBM of 1500 ohms, 100 pF, for IC testing)* Naval Publications and Forms Center 5801 Tabor Avenue Philadelphia, PA 19120
MIL-STD-1686A	*Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment.*
ECMA TR/40	*Electrostatic Discharge Immunity Testing of Information Technology Equipment, 1987.* European Computer Manufacturers Association 114 Rue du Rhône Geneva, Switzerland
EIA-541	*Packaging Material Standard for ESD Sensitive Items* Electronic Industries Association Engineering Department 2001 Eye Street, N. W. Washington, D. C. 20006
EOS/ESD	*Association Glossary of Terms, 1987* EOS/ESD Association, Inc. 201 Mill Street Rome, NY 13440 *Electrostatic Discharge (ESD) Protection Test Handbook, 2nd Edition, 1986.* KeyTek Instrument Corporation 260 Fordham Road Wilmington, MA 01887 *Randy Hull, "Stress Hardening of Damage Thresholds Due to Cumulative ESD Pulse Testing", EOS/ESD Symposium Proceedings, 1988.* Contact EOS/ESD Association (above) for copies.
IEC 801-2	*Electromagnetic Compatibility for Industrial-Process Measurement and Control Equipment, Part 2: Electrostatic Discharge Requirements, Draft 4 (No date).* (HBM: 330 ohms, 150 pF.) International Electrotechnical Commission 3, Rue de Varembé Geneva, Switzerland
UL 84U4	*ESD Grounding System, 1988.* Underwriter's Laboratory Publications Stock 333 Pfingsten Road Northbrook, IL 60062

GLOSSARY

antistatic: Refers to a material that does not cause triboelectric generation. Although some documentation gives this material a resistivity range, this standard defines the term without adherence to a resistivity range. This is in accordance with internal purchase specifications and with external standards such as EIA-541, all ASTM documentation, and EOS/ESD Association standards.

Charged Device Model(CDM):: Charged Device Model, a model characterizing a particular ESD failure mechanism in which a device isolated from ground is charged and is subsequently discharged, causing a high current amplitude, short duration discharge pulse. The CDM typically has a low discharge resistance (less than 10 ohms).

conductor: A material made of metal or impregnated with metal or carbon particles or other conductive materials, or whose surface has been treated with such materials through a process of lacquering, plating, metalizing, or printing. A conductive material for static control purposes shall have a surface resistivity less than 1e+5 ohms/square or 1e+3 ohm-cm if volume conductive. A conductive material is not necessarily antistatic.

electrostatic charge: Electrical charge at rest. The electrical charge is due to the transfer of electrons within a body (polarization) or from one body to another.

Electrostatic Discharge (ESD): The transfer of an electrical charge between bodies at different electrostatic potentials.

Engineering abbreviations -

G (giga) billion or 1e+9
M (mega) million or 1e+6
K (kilo) 1,000 or 1e+3
m (milli) thousandth or 1e-3
u (micro) millionth or 1e-6
n (nano) billionth or 1e-9

Engineering Notation: A numbering system where exponentials are listed with "e+/-#". For example, 100 is equivalent to 1e+2, 0.0723 is equal to 7.32e-2.

EDP failures: These terms are identified in DEC STD 103-0 for use in classifying Digital's electronic data processing (EDP) equipment. (See DEC STD 103-0 for further discussion of this testing and classification). Typically, field operations and other areas understand soft failures to be the first category listed below, and hard failures to be the last two.

soft failure: A failure in EDP equipment that is self-correcting.

hard failure: A failure in EDP equipment requiring operator intervention to correct (no actual equipment damage).

hardware failure: Actual equipment damage to EDP equipment.

ESD: Electrostatic Discharge.

failures: See EDP failures.

GaAs FET: Galium Arsenide Field Effect Transistor.

ground: Effectively connected to the general mass of the earth through a grounding system of sufficiently low impedance and having a current-carrying capability sufficient at all times, and under the most severe conditions which are liable to arise in practice, to prevent any current in the grounding tconductor from causing a harmful voltage to exist between exposed conductive parts of equipment and neighboring conductive surfaces that are likely to be in good contact with the earth.

hard ground: Connection to earth ground without series resistance (see ground).

Human Body Model (HBM): A circuit, for testing purposes, that simulates the ESD waveform of a person.

insulator, electric: A material with surface resistance of greater than 1e+12 and/or a volume resistance of 1e+10.

JFET: Junction Field Effect Transistor.

MOSFET: Metal Oxide Semiconductor Field Effect Transistor.

op-amp (operational amplifier): The op-amp is a DC-coupled, multistage, linear amplifier which, in an ideal device, would have infinite input impedance and infinite gain. While the ideal op-amp remains an unobtainable goal, voltage gains of up to 100,000 or more can be obtained.

Schottky Diode: A diode made by a metal process, such as aluminum and copper or nickel, often a fast switching diode with a forward voltage drop of 0.2 to 0.5 volt.

SCR (Silicon Control Rectifier): A rectifier used to control voltage levels in circuits such as electric drills, incandescent lamps, and the like.

soft ground (see DEC STD 067-3): Connection to hard ground through a protective resistor, typically one megohm.

static dissipative: A property of a material having a surface resistivity of at least 1e+5 ohms/square or 1e+3 ohm-cm volume resistivity, but less than 1e+12 ohms/square surface resistivity or 1e+10 ohm-cm volume resistivity.

triboelectric generation: The generation of electrostatic charges when two pieces of material in intimate contact are separated. Substantial generation of static electricity can be caused by contact and separation of two materials or by rubbing two substances together. (See Triboelectric Series.)

voltage: Electromotive force expressed in volts.

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